TECHNICAL MEMORANDUM

PG Environmental, LLC
Permitting & Compliance Specialists

TO:	Dr. Robert Leidy, U.S. Environmental Protection Agency (EPA) Region 9
FROM:	Dr. Mathias Kondolf, consulting fluvial geomorphologist, Berkeley, California, and James Ashby, PG Environmental, LLC, Golden, Colorado
DATE:	July 27, 2015
SUBJECT:	Conceptual Design for Sonoita Creek, AZ, Technical Review Support (Order Number EP-G149-00241)

1. Purpose

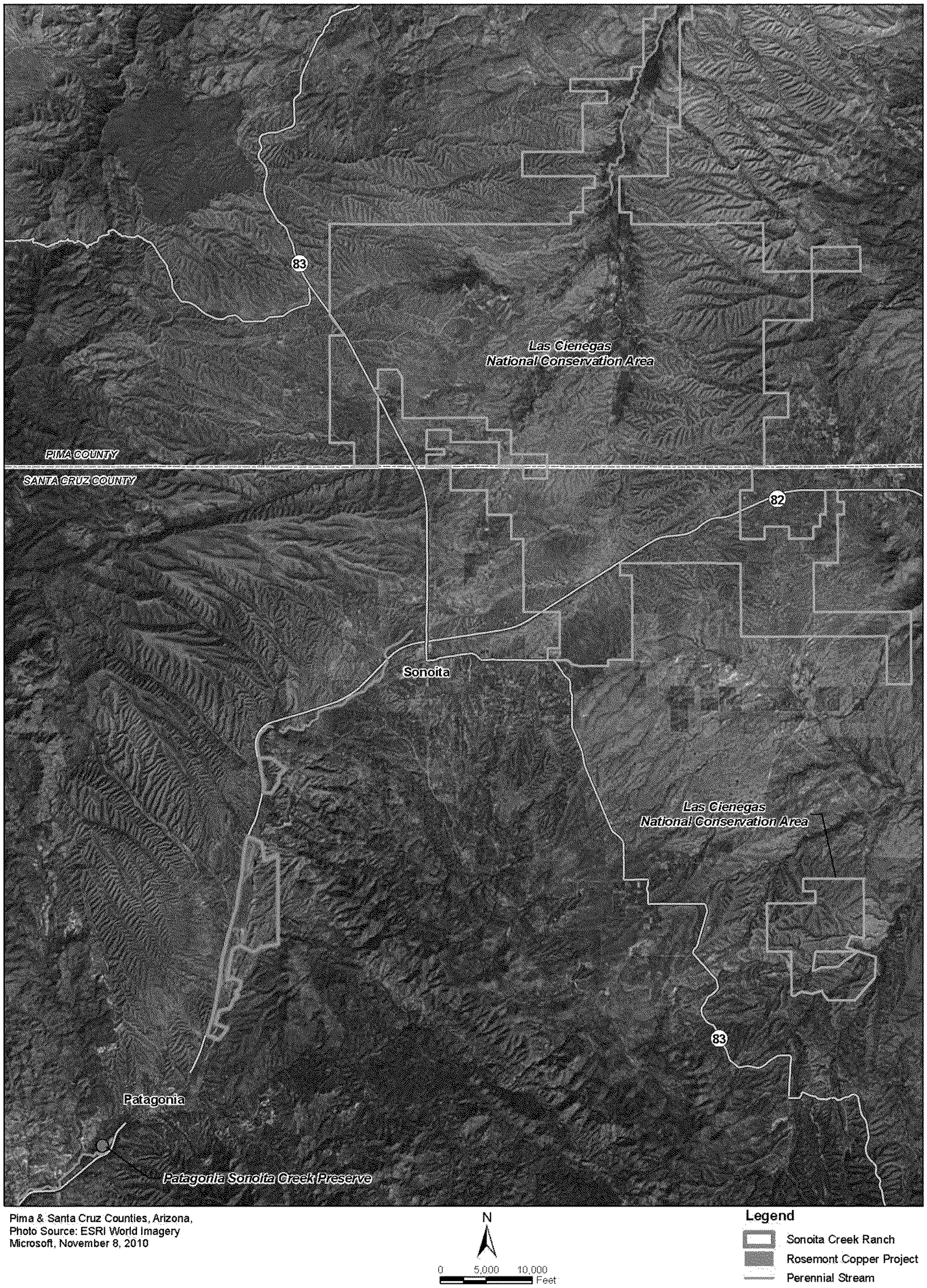
U.S. EPA Contract No. GS-10F-0210U, Task Order 43 EP-G149-00241, "Technical Review Support / Analysis of conceptual design for ephemeral channel adjacent to Sonoita Creek," requests the development of a Technical Memo providing a review of the technical feasibility of the conceptual compensatory mitigation plan to construct ephemeral channels adjacent to Sonoita Creek, near the town of Patagonia, Santa Cruz County, Arizona. Rosemont has employed Water and Earth Technologies (WET), Incorporated to provide the construction design and Westland Resources, Inc. ("Westland") for restoration related to construction. To date, several revisions of the design have been submitted. We used the most recent plan, "Conceptual Design for Ephemeral Channel Adjacent to Sonoita Creek" dated August 12, 2014 (the "WET report") for this technical review. EPA also requested consideration of technical comments prepared by its staff on several earlier versions of the proposed ephemeral channel design. We reviewed those previous comments and determined that our findings were consistent with EPA's comments on prior versions of the design.

2. Summary of Findings

The following findings are discussed in the corresponding numbered sections that follow.

1. The hydrologic modeling significantly overestimates the water available for Sonoita Creek and the proposed constructed channels.
2. Sonoita Creek is a semiarid stream that is characterized by highly dynamic geomorphic and ecological processes, but the hydraulic modeling unrealistically assumed fixed bed elevations.
3. The proposed constructed channels will likely not sustain flow in the specific soil types within the project reach.
4. The existing ecological functions of Sonoita Creek will be reduced by diverting flow from the main channel.
5. There are no comparable reference sites shown or provided for the constructed channel design.
6. The proposed channel design is not self-maintaining or sustainable and will require continual maintenance.
7. The proposed constructed channels do not provide equal ecological value or the same level of functions as the original Sonoita Creek channel.
8. There is no ecological benefit to controlling bank erosion at Sonoita Creek.

Figure 1. Sonoita Creek project reach location map (figure modified from Westland Resources, 2014).



3. Review and Findings

We visited the Sonoita Creek project area on October 30, 2014. Present were Dr. Robert Leidy (U.S. EPA), Dr. Mathias Kondolf (consulting fluvial geomorphologist in Berkeley, California, and full professor at the University of California; see Attachment 1), James Ashby (PG Environmental), Richard Spotts (WET), Ryan Wade (WET), Brian Lindenlaub (Westland), and David Kirzek (Hudbay). We based this technical review of the proposed construction on our observations and conversations from the October 2014 site visit, our review of the WET conceptual design document (version of August 12, 2014), US Geological Survey (USGS) gage data, historical aerial imagery from the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS), and flood estimates from Federal Emergency Management Agency (FEMA) models (as reported in WET 2014). Other professional literature was used as needed, and is cited within the text. A complete listed of sources is provided at the end of this technical memo.

Based on our technical review of the WET report we present the following findings:

1) **The hydrologic modeling significantly overestimates the water available for Sonoita Creek and the proposed constructed channels.** To support its conceptual design of the constructed mitigation channels, WET performed hydrologic analyses to determine flood frequencies and resultant flow through the area of interest. WET used the HEC-HMS and SEDCAD models to determine the peak discharge rates for various return interval storms including the 2-year, 10-year and 100-year return intervals. WET then routed the resultant peak discharges through the channels using the HEC-RAS model to determine the water surface profiles through the study reaches, as discussed below. Our review did not include a detailed technical review of the modeling data or output, but rather was limited to the material presented in the WET report.

   It is well known that hydrologic models (such as HEC-HMS and SEDCAD) are sensitive to the input variables, and can produce a wide range of results depending on the values selected, even when using a reasonable and plausible range of values. The WET report calculated flows for some return intervals that were considerably higher than other estimates, including those based on historical 1930-1972 gage data collected by the US Geological Survey at a station located about 7 miles downstream, and the peak flows modeled by FEMA at the Harshaw Creek confluence about 2 miles downstream of the project reach. The values of peak runoff per square mile (cfs/mi^2) calculated by these various methods are presented below (Table 1). For the 2, 5, and 10-year flows (flows that would be expected to yield ecological benefits by flowing through the new channels), the WET results (expressed as unit peak flows, cfs/mi^2) using the HEC-HMS and SEDCAD models were about 2-3 times larger than the unit peak flows indicated by a flood frequency analysis of the actual (historical) measured flows at the USGS Patagonia gage and the flows modeled by FEMA. The large discrepancy between flows measured/modeled by the USGS/FEMA and the model results presented by WET emphasize the speculative nature of much of the modeling work. As a consequence, there is significant uncertainty whether the flows assumed by the project designers would actually occur with the frequency assumed in the project design. Moreover, in interpreting the maps showing the predicted extent of flooding at various return intervals, the flows assumed by the hydraulic models are 2-3 times greater than indicated by the actual gage data and independent modeling for FEMA, and thus there is a significant likelihood that actual flows will be much less than assumed in the WET report. This means that the constructed channels will not receive the amount and frequency of water predicted.

Table 1. Unit Flood Discharges (cfs/mi^2) From Different Methods

Return Interval (y)	USGS Patagonia Gage**	Flood Insurance Study+	WET: HEC-HMS (using SCS-UH)*	WET: SEDCAD (using Double Triangle)*
100	76.8	125.2	254.5	189.8
50	65.1	93.5	210.5	157
10	38.9	39	122.0	90.1
5	28.1	-	88.5	64.9
2	14.1	-	51.8	37.8

** Peak flows from flood frequency analysis for USGS gage Sonoita Ck at Patagonia (1930-1972), drainage area = 209 mi^2

+ Peak flows from FEMA 2012 for Sonoita Ck at Harshaw Ck confluence, drainage area = 137.8 mi^2, as presented in Table 1 of WET 2014

* Peak flows as modeled by WET for "design point," 38.7 mi^2, from Table 3 of WET 2014

2) **<u>Sonoita Creek is a semiarid stream that is characterized by highly dynamic geomorphic and ecological processes, however the hydraulic modeling unrealistically assumed fixed bed elevations.</u>** Flow in semiarid streams such as Sonoita Creek is highly variable, ranging from no flow most of the time for most reaches (including the project reach) to intense flash floods (Stein et al. 2011, Levick et al. 2008). Flow records at the Sonoita Creek gauge, which continuously recorded discharge from 1930-1972, and for which annual instantaneous peak flows were available from 1930-1983, demonstrate the highly variable flow pattern, with long periods of no flow, interrupted by flash floods up to a maximum of 16,000 cfs recorded on 02 October 1983 (US Geological Survey gauge, Sonoita Creek near Patagonia, Gauge No. 09481500, data available online at *water.usga.gov*). Although sediment transport measurements are lacking, it is clear that sediment loads in Sonoita Creek, including coarse sand and gravel, tend to be high, and the bed experiences active erosion and deposition, banks erode, and channels shift during large floods. As with other dynamic rivers, the processes of active erosion and deposition create a diverse and frequently changing set of geomorphic surfaces (with different water tables and disturbance frequencies), which in turn facilitate establishment of riparian vegetation adapted to site conditions, and ultimately to high biodiversity in riparian areas (Florsheim et al. 2008, Piégay et al. 2005).

WET used the HEC-RAS hydraulic model to route the modeled flows through the Sonoita Creek channel and the proposed artificial secondary channels. Hydraulic models such as HEC-RAS rely on detailed and precise input of physical channel geometries. Cross sections of the actual channel and the proposed constructed channels were input into the model to predict water surface elevations. It is the water surface elevations relative to channel bed elevations at the points where flow is expected to leave the main channel that will determine how much water stays in the main channel and how much spills into the proposed constructed channels. However, the elevations of these points, as well as the angle at which flow is diverted from the main channel, will change over time with normal fluvial geomorphic processes in Sonoita Creek. There is no geomorphic justification to expect that the channels and their junctions will remain unchanged. Even if bank protection and buried riprap were used, experience shows that in such unstable alluvial environments it is difficult to maintain constructed features such as these in a static state. For instance, on the Rail X Ranch Hills North property Lot 3 at the confluence of Adobe Canyon and Sonoita Creek (refer to Appendix, Photograph 1 and 2, as well as Sheet 1 in the end material of the WET report) there is a proposed take-off point for a constructed channel. This area was observed to be very dynamic, and receives high sediment loads from the input of Adobe Canyon. A take-off point into the proposed constructed channel in this area would be subject to the constant influx of sediment and changing channel geometry due to highly dynamic alluvial stream behavior. It was additionally observed for this same proposed constructed channel on the Rail X Ranch Hills North property that in order to accommodate the property ownership currently available to the project, the tie back of the proposed constructed channel into Sonoita Creek must occur before the southern end of Lot 1. This connection would require a specific angle of connection in order to accommodate those property constraints, which would be challenging to maintain given the general dynamic nature of Sonoita Creek, as well as the influence of the proximity to the Adobe Canyon confluence.

Sonoita Creek is a dynamic alluvial channel in a semiarid environment and was observed during the field visit to experience active erosion of its bed and banks, deposition of sediment, and shifts in channel location. Our field reconnaissance was conducted the month after an intense rainfall and runoff in mid-September, and our observations confirmed that the channel displays such active behavior. Especially in the lower-most mile of the proposed mitigation reach, it was observed that during the September 2014 stormflow prior to our visit, Sonoita Creek experienced channel migration, erosion of steep outside banks and deposition of point bars, undercutting and recruitment of trees into the channel, and overbank flow across a portion of its floodplain (see Appendix, Photograph 7 and 8). The downstream-most 6,000 feet of Sonoita Creek located on the Sonoita Spring Ranch property, particularly within Lot 1 through 4, as well as Lot 7 of the Rail X Ranch property, is especially dynamic and complex. We observed a secondary channel developed parallel and east of the main Sonoita Creek channel, and complex patterns of scour and deposition that were created as flow spilled from the main channel into the secondary channel through a wooded island over a distance of approximately 600 ft. The resulting complex fluvial forms provide excellent substrate for establishment of cottonwoods and other riparian trees, and excellent, diverse habitats for birds and other animals. This lower mile of the project reach of Sonoita Creek on the Sonoita Spring Ranch and Rail X Ranch property lots have especially good habitat, with abundant willows and cottonwoods growing on recently established, fresh surfaces that are frequently flooded or subject to lateral erosion.

As natural channel change occurs in Sonoita Creek, the proposed constructed channel geometries will also change, and these changes would quickly render the model assumptions of channel geometry invalid. Even small changes in grade, or cross sectional geometry could have a significant impact on the flows that might be diverted down a constructed channel. For example, all six of the takeoff points we observed from the main Sonoita Creek channel into the constructed channels are modeled with little margin for error. A slight change in elevation of the channel bed could be the difference between having water flow in the constructed channels as designed, rarely flow, or never flow. The underlying basis of the proposed mitigation approach assumes that channels will remain stable or could be restored with minor "repairs" after floods, but this assumption is not supported by theory or experience for channels such as Sonoita Creek.

3) **<u>The proposed constructed channels will likely not sustain flow in the specific soil types within the project reach.</u>** The Sonoita Creek valley bottom consists primarily of alluvial deposits. In terms of mapped soil units, it is dominated by Grabe-Comoro complex (GbB) soils of gravelly sandy loam to sandy loam composition, that receive a hydrologic soil group classification (HSG) of Group A (refer to Figure 2a and 2b). Group A soils are characterized by high infiltration rates, low runoff potential, and a high rate of water transmission. The Sonoita Creek floodplain also has a lesser percentage of Pima soils (Pm), a clay loam that receives a HSG classification of Group C. Group C soils are characterized by slow infiltration rates and slow water transmission.

   Transmission losses due to infiltration into the bed and banks are high in semiarid ephemeral streams, and multiple researchers have demonstrated that except during the highest flows, there is significant loss of in-stream flow due to seepage as the flow proceeds downstream in alluvial valleys (Levick, et al. 2008). The WET report (p.12) notes that transmission losses for streams like Sonoita Creek have been reported as high as 17-29%. Approximately half of the constructed pilot channels as proposed in the plan would be excavated into the highly permeable Grabe-Comoro complex soils, resulting in high transmission losses. Any portion of the flow that entered the newly constructed channels during low to moderate flow rate events, such as those that occur at a high frequency annual scale, would likely not be sustained, and likely not return to the main Sonoita Creek channel. Sediment drops out of suspension as infiltration occurs and flow drops in velocity, depositing new material in the channel. Resulting aggradation may fill the newly constructed channels, further restricting the ability of flows to be diverted and for any diverted flow to successfully return to the main Sonoita Creek channel, particularly at the downstream reaches of constructed channels. Continued aggradation in the constructed channel could eventually create an abandoned, non-functional channel. The overall result would be a loss of habitat in the main channel of Sonoita Creek and a failure to create new habitat in the constructed channels, therefore failing to meet the stated goals of the proposed design in the WET report.

Figure 2a. Hydrologic soil group map and color-coded ratings for Sonoita Creek area (see next page for map legend).

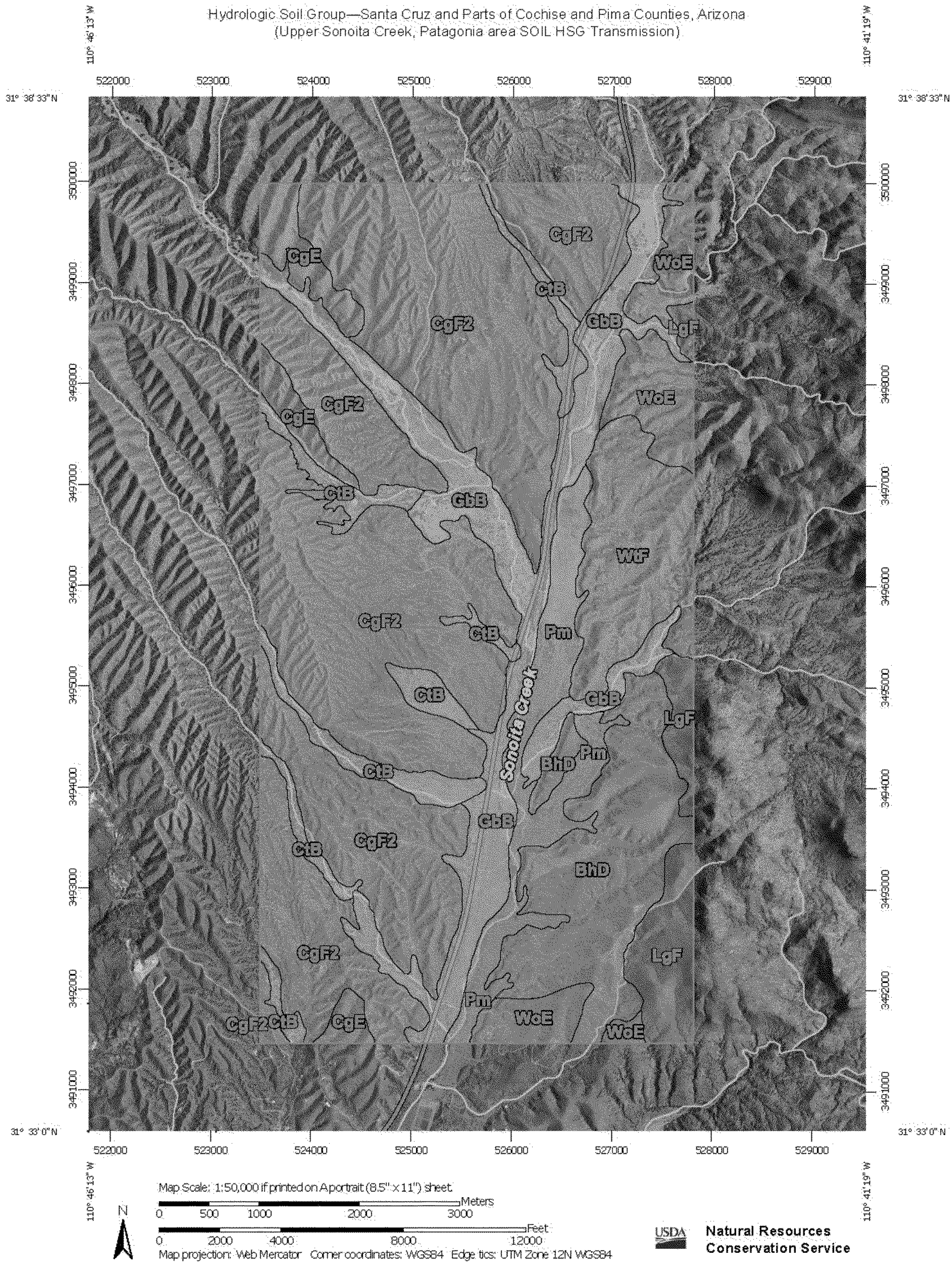


Figure 2b. Map legend and symbol definitions for hydrologic soil group map of Sonoita Creek area.

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Hydrologic Soil Rating

A

C

D

Water Features

Streams and Canals

Transportation

Major Roads

Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise the AOI were mapped at 1:20,000.

USDA **Natural Resources Conservation Service**

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Santa Cruz and Parts of Cochise and Pima Counties, Arizona
Survey Area Data: Version 8, Sep 14, 2014

Date(s) aerial images were photographed: Nov 8, 2010—May 29, 2011

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydrologic Soil Group— Summary by Map Unit — Santa Cruz and Parts of Cochise and Pima Counties, Arizona (AZ667)

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
BhD	Bernardino-Hathaway association, rolling	C	894.4	9.8%
CgE	Caralampi gravelly sandy loam, 10 to 40 percent slopes	C	280	3.1%
CgF2	Caralampi gravelly sandy loam, 10 to 60 percent slopes, eroded	C	4,403.60	48.2%
CtB	Comoro soils, 0 to 5 percent slopes	A	453.2	5.0%
GbB	Grabe-Comoro complex, 0 to 5 percent slopes	A	1,190.20	13.0%
LgF	Lampshire-Graham-Rock outcrop association, steep	D	350.1	3.8%
Pm	Pima soils	C	500.5	5.5%
WoE	White House-Caralampi complex, 10 to 35 percent slopes	C	475.9	5.2%
WtF	White house-hathaway association, steep	C	593	6.5%
Totals for Area of Interest			**9,140.8**	**100.0%**

4) **<u>The existing ecological functions of Sonoita Creek will be reduced by diverting flow from the main channel.</u>** In the lower 6,000 feet of the project reach on the Sonoita Spring Ranch property (Lots 1 through 8) and Lot 7 of the Rail X Ranch property, the channel is especially active and complex. Here the creek supports numerous Fremont cottonwoods (*Populus fremontii*), which propagate after overbank flooding that encourage seed germination through the moistening of soils and deposition and/or burying of the seeds (Henson, et al. 2008). This part of the creek is highly dynamic and complex, and supports valuable riparian habitat (see Appendix, Photographs 6 through 10). The best "restoration" approach for such a healthy stream reach is to preserve it (Piégay et al. 2005, Beechie et al. 2010, Kondolf 2011). Within such dynamic riparian corridors as Sonoita Creek, there is high species turnover and high biodiversity (Stein et al. 2011). These riparian corridors are important for the ecology of the wider region. For example, in the Inyo National Forest of California, riparian areas constitute only 0.4% of the landscape, but about 75% of local wildlife species require riparian areas at some point in their life cycle (Kondolf et al 1987). If a portion of the main Sonoita Creek channel is diverted, the flow available to drive active channel processes and overbank flow will be reduced, and these processes will not occur as frequently as they occur at present. In high functioning reaches of Sonoita Creek reducing flow may, for instance, result in lower propagation and reduced success of cottonwoods. Thus the creation of constructed channels that divert flow from Sonoita Creek will likely result in net ecological deterioration by degrading an existing channel with high ecological function. It was additionally observed on the Sonoita Spring Ranch property, Lots 1 through 5 and Lot 7 (refer to Sheet 1 in the WET report), that a minimum 32 acre section of existing, regionally rare, native big sacaton (*Sporobolus wrightii*) grasslands would be impacted by the proposed channel construction (see Appendix, Photograph 5). This grassland already functions as a floodplain ecosystem, and would only be degraded and destroyed by the incision and excavation of new channels into the flood plain.

5) **<u>There are no comparable reference sites shown or provided for the constructed channel design.</u>** The only reference site offered in the plan as a successful restoration project is an ephemeral stream on the Vermejo Park Ranch property near Raton, New Mexico, which is located in a different climatic and ecological region than Sonoita Creek. Raton, New Mexico is in the Western Cordillera ecological region, a sub-region of the Northwestern Forested Mountains, which is characterized by ponderosa pine, Douglas fir, lodgepole pine, and trembling aspen. Climate in this ecological region ranges from subarid to arid, with tendencies towards subarid at elevations like Raton (6,885 ft.) and higher elevations immediately to the west (7,000-8,000 ft., including Raton Pass at 7,834 ft). Sonoita Creek near Patagonia, Arizona (4,055 ft.) is in the Western Sierra Madre Piedmont ecological region, a sub-region of the Southern Semi-Arid Highlands ecological region, and is characterized by grasslands, western juniper, cactus, and cottonwood. Climate in this ecological region is semi-arid, often interrupted by periodic droughts.

   Vermejo Park Ranch and Sonoita Creek lie within two different ecological and climatic regimes with different plant populations, soils, and different channel characteristics. The experience with the constructed channels at the Raton, NM reference site is not applicable to Sonoita Creek. The current and future behavior of Sonoita Creek has not been demonstrated, either through comparable reference sites or intensive study of Sonoita Creek itself.

6) **The proposed channel design is not self-maintaining or sustainable and will require continual maintenance.** As we observed during the field visit, semiarid ephemeral streams such as Sonoita Creek change their channel morphology during floods, which may occur only infrequently (Levick et al., 2008). Even if the proposed constructed channels function as expected during frequent, small floods (e.g., occurring every year or two), they are likely to fail or alter significantly during larger floods (e.g., occurring on a decadal scale). Those changes may occur at a point in the future when "maintenance" cannot be performed, either due to lack of funds or lack of obligation by a responsible party. Since the plan calls for a high degree of monitoring after initial construction to evaluate the performance of the constructed channels, and then suggests that modification of the design based on those observations will be required, this design is not self-sustaining.

The WET report (p.13-14) states that the proposed constructed channels were designed based on "characteristics for template stream reaches in the project area" (without specifying the characteristics), the use of a commercial model called "Natural Regrade with GeoFluv," and the Rosgen stream classification system. The objective was to create a "natural-looking" channel with parameters of a Rosgen "C" channel, and a cross section "typical of stable natural channels."

However, many constructed channels designed with this kind of approach have not proved stable. Among the best documented cases are Deep Run, Maryland, where the constructed project failed within a few years (Smith and Prestegaard 2005), Cuneo and Uvas Creeks, California, where the constructed channels failed within years and months, respectively (Kondolf 2006), and multiple such projects in North Carolina, where of 40 projects evaluated, 70% were no longer functioning as designed by 2007 (Nagle 2007). Given that attempts to construct stable channels have had, at best, mixed success even in more humid-climate stream systems, the assumption that such constructed channels at Sonoita Creek would remain stable in a dynamic semiarid system is unlikely to be true.

The WET report also proposes to install bank protection in three locations, as "buried riprap", which would presumably be exposed if the channel migrated into the protected bank. Hard elements such as riprap are likely to induce other channel changes by reflecting stream energy and accelerating erosion upstream, downstream, and/or on the opposite bank. The potential negative impacts of riprap were not considered in the WET report.

Geomorphic land forms - the WET report acknowledges that the extensive excavation of the secondary channels would result in over a million cubic yards of spoil material, which must be somehow disposed of. Approximately 132,000 cubic yards of spoil material will be used for "fill and recontouring," 32,000 cubic yards to be disposed of at Rail X Ranch, and 838,000 cubic yards of spoil would be placed in massive spoil piles contoured into what the report terms "geomorphic landforms." The spoil piles would be shaped to have swales or channels to carry runoff from the surface, evidently with the goal that the spoil piles would be "erosionally stable" without requiring riprap or other stabilization measures.

The creation of these spoil piles can be expected to have impacts in at least two significant ways. First, excavation of a million cubic yards of spoil is a massive undertaking, with inevitable impacts of heavy equipment compacting sensitive soils, disrupting the existing topography, etc.

Moving 838,000 cubic yards to the spoil piles by truck would in itself be a disruptive action. Assuming dump trucks with a capacity of 10 cubic yards each, this would involve 83,800 dump truck trips.

Once the spoil piles are built and contoured, it is implausible that they would not be subject to some erosion, even with the contouring proposed. These would be significant piles of disturbed soil and alluvial sediment, lacking in geologic or soil structure, which would perched above the surrounding landscape and inherently prone to erosion. Moreover, such spoil piles inevitably experience differential settlement, so the constructed drainage pathways may not work as planned. The WET report does not present an analysis of the geomorphic, ecological, and visual impacts of the proposed spoil piles.

The WET report also refers to over 91,800 cubic yards of spoil material to be "spread" on Sonoita Creek Ranch as a 0.8-ft fill layer over 70 acres of agricultural fields to be "recontoured". The potential for this distributed spoil material to impact existing resources and to erode is not addressed in the WET report.

7) **The proposed constructed channels do not provide equal ecological value or the same level of functions as the original Sonoita Creek channel.** The project design proposes to split flow from the existing Sonoita Creek channel at six takeoff point locations, and then return flow to the main channel further downstream, creating an artificial multiple-channel morphology. The splitting of flow is to be accomplished through a combination of on-grade channels that receive a portion of any flow in the main channel and some slightly above-grade channels that are designed to receive a portion of the flow only during overbank conditions in the main Sonoita Creek channel. Such multiple, isolated, stable channels do not commonly occur in semiarid ephemeral streams (Levick et al., 2008). An attempt to create separate, parallel channels, each of which could count as a distinct, separate waterway, is unlikely to be a stable configuration.

   The WET report implies that Sonoita Creek in the project reach formerly had distinct, stable, multiple channels from the use of terms such as "restore and extend various reaches of stream channel" (p.1) and "reestablishing the benefits associated with typical unconstrained channel morphology in the area" (p.3). The WET report did not present any historical evidence to support the notion that Sonoita Creek formerly had multiple, stable channels. Fluvial geomorphologists usually consult historical sources for insights into river behavior that can inform restoration approaches (Kondolf and Larsen 1995). While a full historical channel analysis was beyond the scope of our review, we did obtain aerial photographs covering the Sonoita Creek valley in 1935. This historical imagery demonstrates that, as of 1935, Sonoita Creek was mostly a single-thread channel through the project reach (Figure 3, 3a, and 3b). The historical imagery does not display multiple, stable channels on Sonoita Creek, and as noted above, such a stable multi-channel configuration would not be expected in a dynamic semi-arid stream such as Sonoita Creek.

8) **There is no ecological benefit to controlling bank erosion at Sonoita Creek.** The plan asserts there will be benefits to controlling bank erosion along Sonoita Creek and presents an example of a high vertical cohesive bank, which is actively eroding. Such high, eroding banks occur naturally when a stream channel impinges into valley side slopes. There is nothing

inherently wrong with such banks, and in fact such sites can be important sources of sediment to the channel (Florsheim et al. 2008). Within the project reach, we observed that this condition is rare rather than common. The WET report presents no information to indicate that Sonoita Creek is experiencing unusual, artificially-elevated bank erosion rates. Thus, the available evidence suggests that bank erosion highlighted in the WET report and observed by us during the site visit is a natural process appropriate to this type of stream and necessary for proper ecological function.

4. Conclusions

It is our conclusion that the overall WET plan overestimates the flow available and does not take into account the dynamic nature of Sonoita Creek. The plan as designed is not self-sustaining and would require ongoing maintenance in order to maintain the channel geometry conditions established at the time of construction. Similar successful restoration projects in comparable environments are not provided, and furthermore it is not demonstrated that additional habitat of equal ecological value and function will be created by constructing new channels. Rather, the overall result of cutting additional channels in the relatively permeable soil of the Sonoita Creek floodplain would likely be numerous dry, abandoned channels, and an overall degradation of the quality and function of Sonoita Creek. Given our observations, review of the WET report, and consideration of the environmental and ecological conditions at Sonoita Creek, it is our professional opinion that the WET plan will not function as designed. Our conclusions are consistent with the EPA's previous reviews and comments.

Figure 3. Patagonia and Sonoita Creek area from 1935 Fairchild flight number C-3250. The current modern day location of state highway 82 is shown in red for reference.

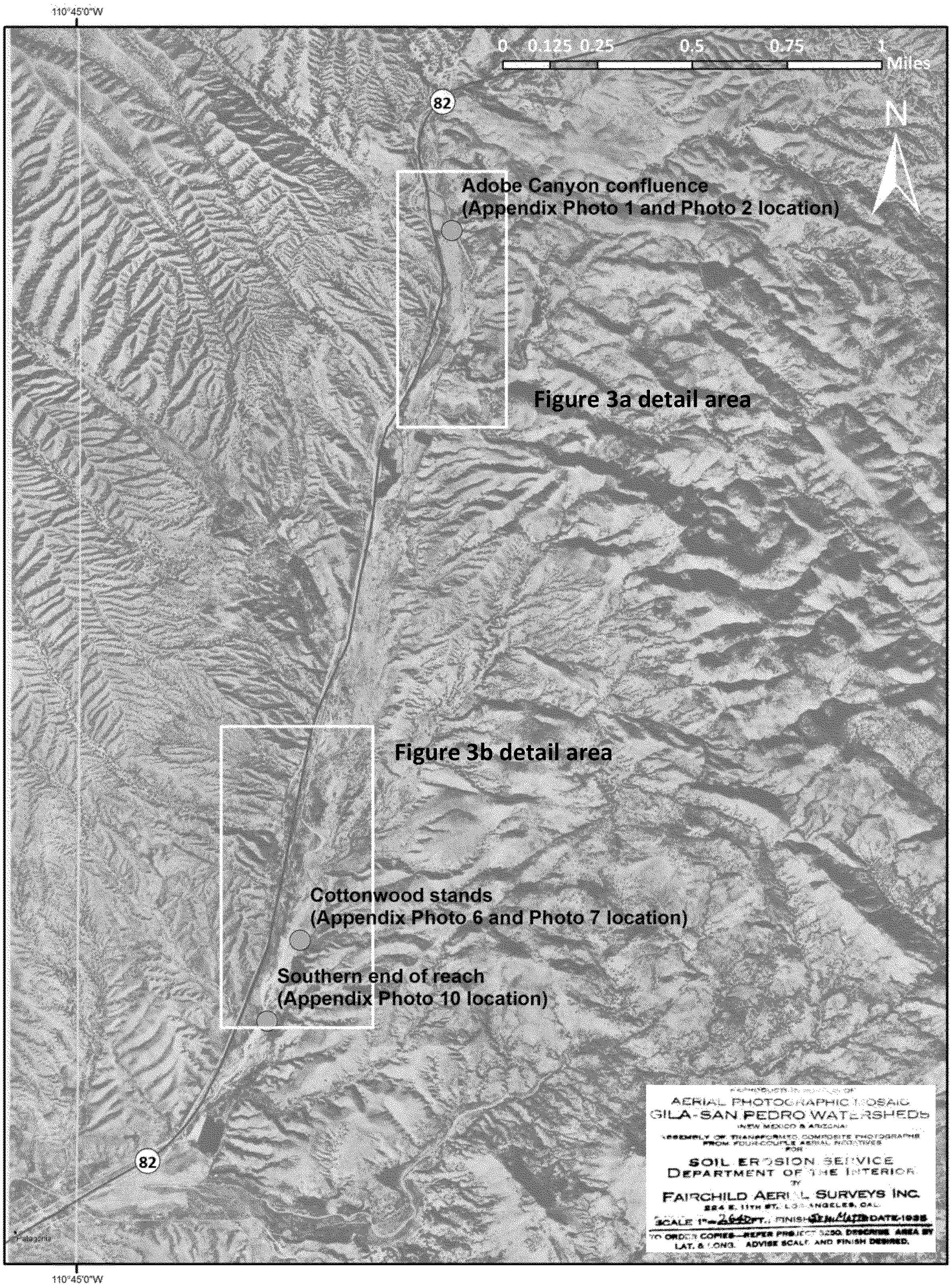
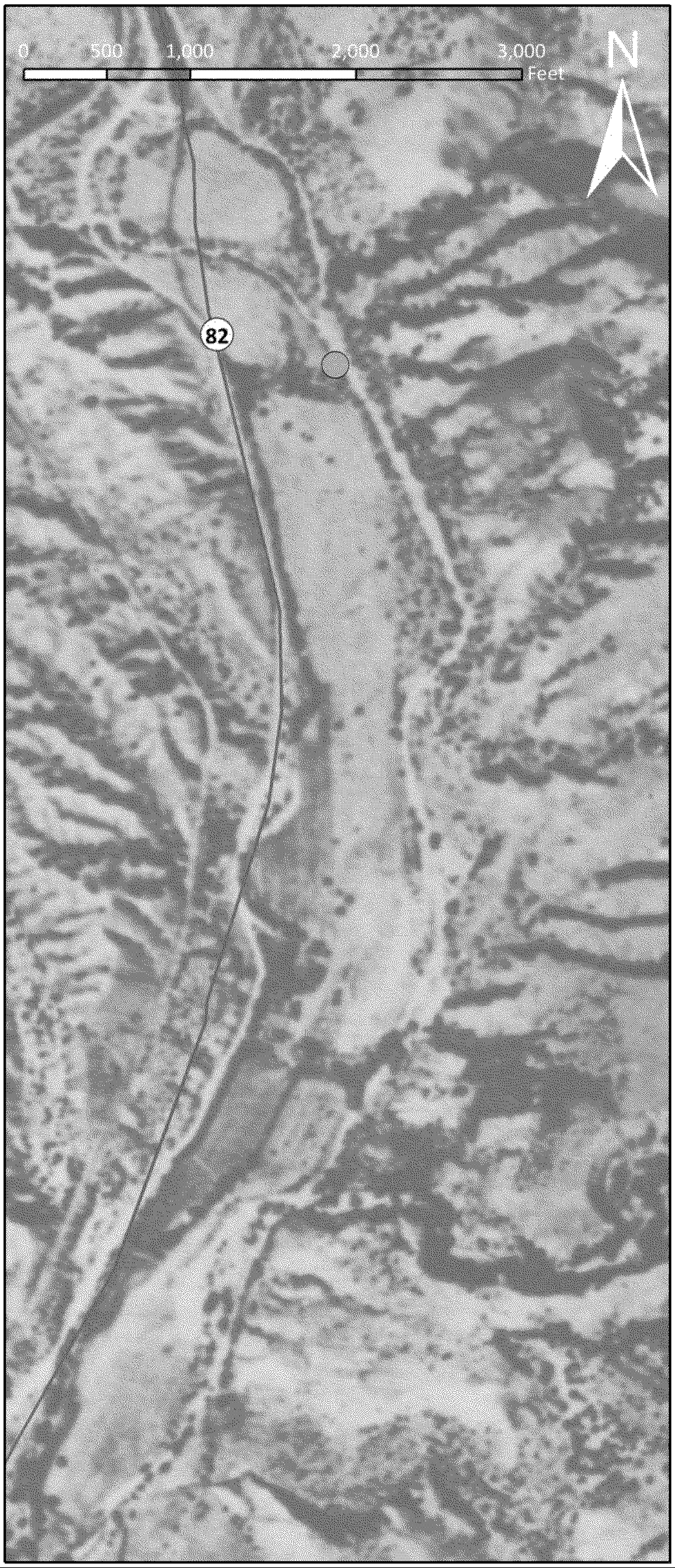
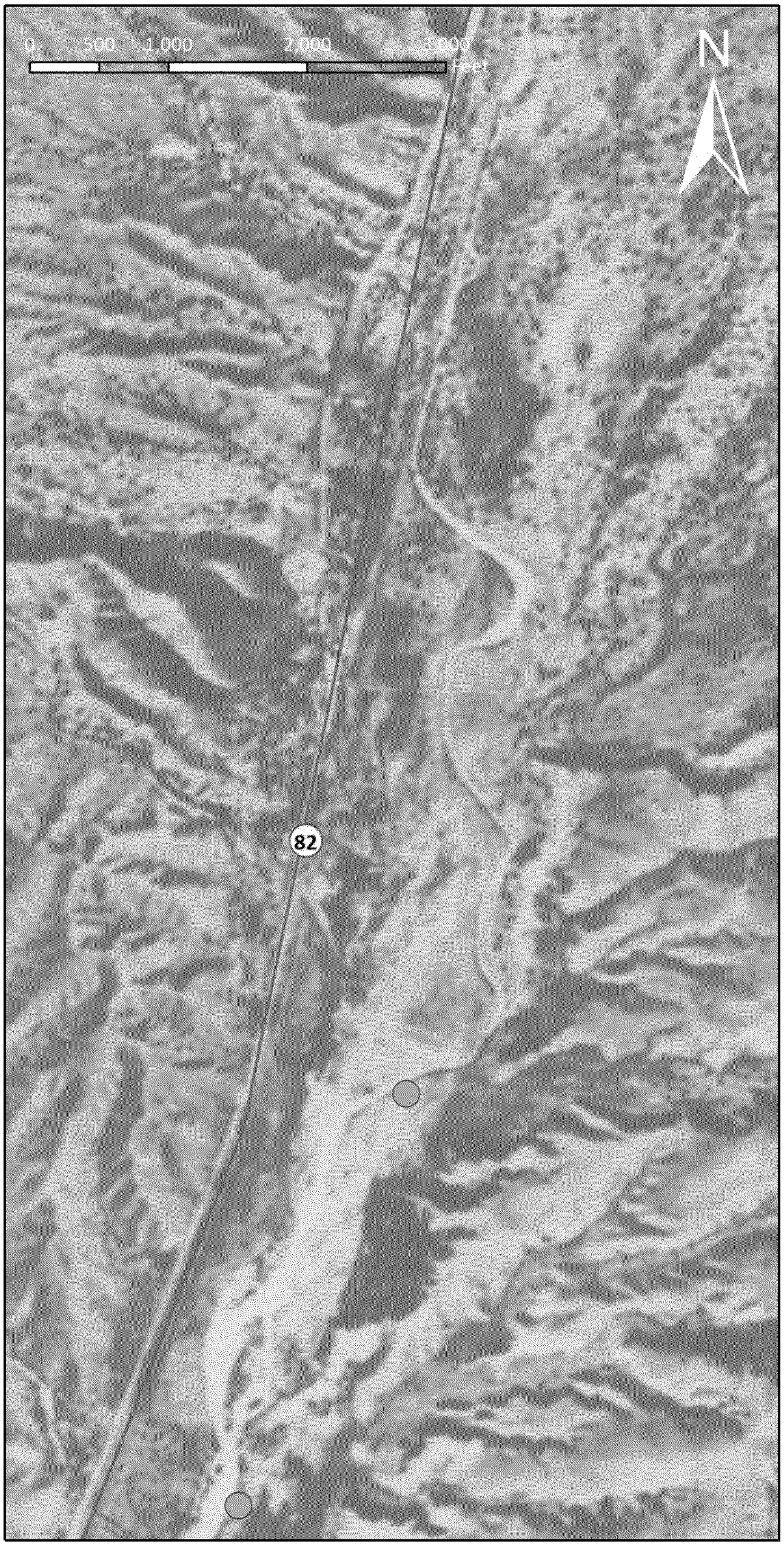


Figure 3a. Detail area from Figure 3. The current modern day location of state highway 82 is shown in red for reference.



ED_001040_00005973-00014

Figure 3b. Detail area from Figure 3. The current modern day location of state highway 82 is shown in red for reference.



5. Sources cited

Beechie, T.J., Sear, D.A., Olden, J.D., Pess, G.R., Buffington, J.M., Moir, H., Roni, P., and Pollock, M.M. 2010. Process-based principles for restoring river ecosystems. BioScience 60: 209-222.

Florsheim, J.L., Mount, J.F., and Chin, A. 2008. Bank erosion as a desirable attribute of rivers. Bioscience 58(6): 519-529.

Henson, J., Stevens, M., and Fenchel, G. 2008. Plant guide for Fremont's Cottonwood (Populus fremontii S. Wats.). USDA-Natural Resources Conservation Service, National Plant Data Center. Baton Rouge, LA.

Levick, L., Fonseca, J., Goodrich, D., Hernandez, M., Semmens, D., Stromberg, J., Leidy, R., Scianni, M., Guertin, D.P., Tluczek, M., and Kepner, W. 2008. The Ecological and Hydrological Significance of Ephemeral and Intermittent Streams in the Arid and Semi-arid American Southwest. U.S. Environmental Protection Agency and USDA/ARS Southwest Watershed Research Center, EPA/600/R-08/134, ARS/233046, 116 pp.

Kondolf, G.M. 2006. River restoration and meanders. Ecology and Society. [online] URL: http://www.ecologyandsociety.org/vol11/iss2/art42/

Kondolf, G.M. 2011. Setting goals in river restoration: when and where can the river 'heal itself'? in Simon, A. et al (eds) Stream Restoration in Dynamic Fluvial Systems: Scientific Approaches, Analyses, and Tools. Geophysical Monograph Series Vol.194 pp.29-43. American Geophysical Union, Washington DC. DOI: 10.1029/2010GM001020.

Kondolf, G.M., and M. Larson. 1995. Historical channel analysis and its application to riparian and aquatic habitat restoration. Aquatic Conservation 5:109-126.

Kondolf, G.M., Webb, J.W., Sale, M.J. and Felando, T. 1987. Basic hydrologic studies for assessing impacts of flow diversions on riparian vegetation: Examples from streams of the eastern Sierra Nevada, California. Environmental Management 11:757-769.

Nagle, G. 2007. Evaluating 'natural channel design' stream projects. Hydrol. Process., 21: 2539–2545. doi: 10.1002/hyp.6840

Piégay, H., Darby, S.E., Mosselman, E., and Surian, N. 2005. The erodible corridor concept: applicability and limitations for river management. River Research and Applications 21: 773-789.

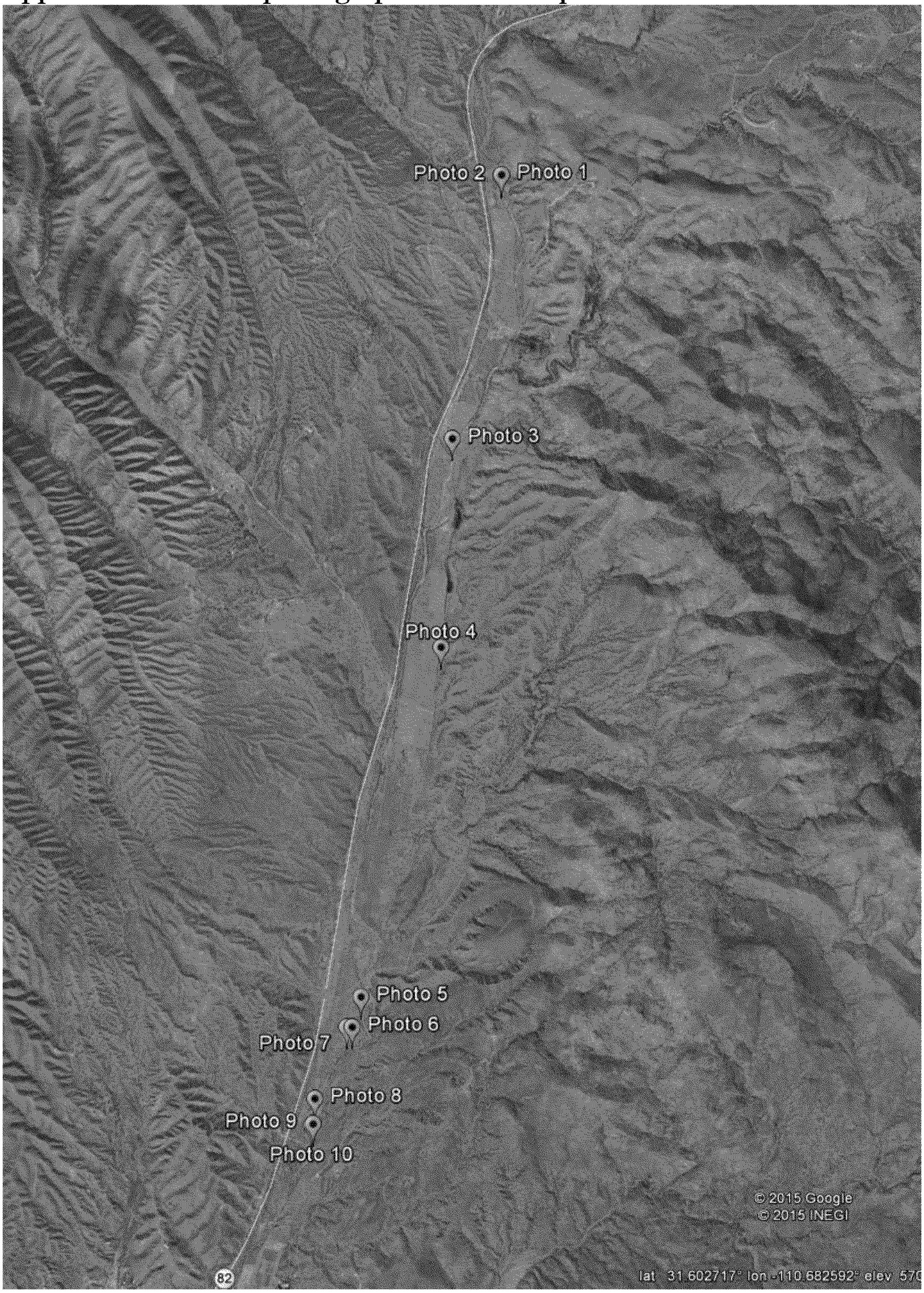
Smith, S. M., and Prestegaard, K. L. 2005. Hydraulic performance of a morphology-based stream channel design. Water Resources Research 41: doi: 10.1029/2004WR003926.

Stein, E.D., Vyverberg, K., Kondolf, G.M., and Janes, K. 2011. Episodic stream channels: imperatives for assessment and environmental planning in California. Proceedings of a special technical workshop, November 2010, Costa Mesa, California. Southern California Coastal Water Research Project Report No. 0645.

Westland Resources, Inc. (Westland), 2014, Revised Habitat Mitigation and Monitoring Plan, Rosemont Copper Project.

U.S. Department of Agriculture Forest Service (USFS), producer, 2013. Final Environmental Impact Statement for the Rosemont Copper Project, A Proposed Mining Operation, Coronado National Forest, Pima County, Arizona, U.S. Department of Agriculture, Forest Service, Southwestern Region, Tuscon, 212 p.

6. Appendix – Site visit photograph location map.



Photograph 1: Confluence of Adobe Canyon and Sonoita Creek. Looking north, Adobe Canyon channel to left, Sonoita Creek channel to right.

Photograph 2: Looking south from Photograph 1 location, immediately after confluence of Adobe Canyon and Sonoita Creek.

Photograph 3: Example of a typical section of the main Sonoita Creek channel, looking south from photograph location.

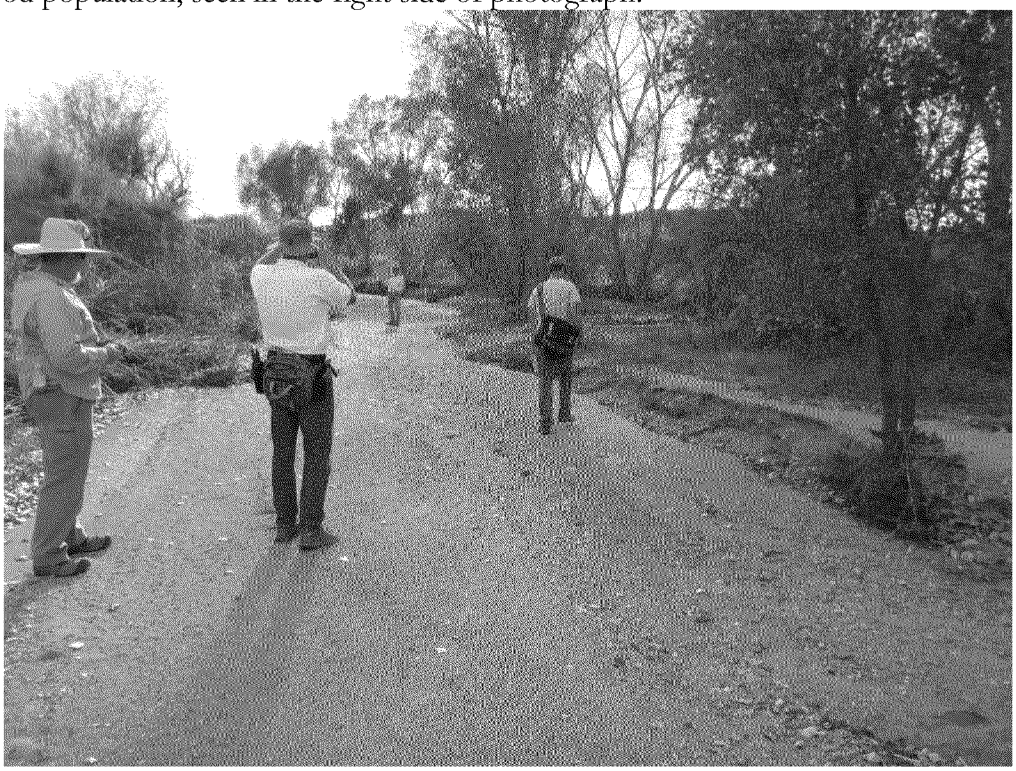
Photograph 4: View looking west across former agricultural field.

Photograph 5: View looking west from photograph location at example of big sacaton (*Sporobolus wrightii*) grasslands.

Photograph 6: Looking south, downstream in main Sonoita Creek channel at high water debris around cottonwood tree trunk (clipboard and people for scale).

Photograph 7: Additional view looking south within main Sonoita Creek channel at example of cottonwoods population on left bank that are supported by periodic flooding.

Photograph 8: View looking north in main Sonoita Creek channel at another example of the cottonwood population, seen in the right side of photograph.



Photograph 9: View looking south within the main Sonoita Creek channel at a concrete road crossing. Further examples of the cottonwood population are seen in the distance.

Photograph 10: View immediately north from same location in Photograph 9, with additional examples of the cottonwood population.

7. Attachment – Resume of Dr. Mathias Kondolf

G. MATHIAS KONDOLF, PhD
Consultant in Fluvial Geomorphology, Environmental Planning, and Hydrology
2241 Ward Street, Berkeley California 94705 USA
Professor of Environmental Planning, University of California Berkeley
mattkondolf@gmail.com

PROFESSIONAL QUALIFICATIONS

G. Mathias (Matt) Kondolf is a fluvial geomorphologist and environmental planner, specializing in environmental river management and restoration. As Professor of Environmental Planning at the UC Berkeley, he teaches courses in hydrology, river restoration, and environmental science. His research concerns human-river interactions broadly, with emphasis on management of flood-prone lands, sediment management in reservoirs and regulated river channels, and river restoration. Current research includes the Lower Colorado, Sacramento, Trinity, and Klamath Rivers of California/Oregon; the Apalachicola River, Florida; and the Lower Mekong River. He has provided expert testimony before the US Congress, the California legislature, California Water Resources Control Board, the International Court of Justice and the Court of Arbitration Indus Water Treaty 1960, both in the Hague, and in various legal proceedings in the US. Recipient of two Fulbright awards, the Merit Award from the Council of Educators of Landscape Architecture, and a fellow of the Landscape Architecture Foundation, he was appointed as Clarke Scholar at the Institute for Water Resources in Washington, to two National Academy of Science panels, the Calfed Ecosystem Restoration Science Board, and the Environmental Advisory Board to the Chief of the US Army Corps of Engineers. He is author of over 100 papers in international scientific journals and books, and his book *Tools in Fluvial Geomorphology* (John Wiley & Sons) is a reference in the field, with the 2nd edition forthcoming in 2015.

EDUCATION

The Johns Hopkins University. PhD, Geography and Environmental Engineering 1988.

University of California at Santa Cruz. MS, Earth Sciences 1982.

Princeton University. AB cum laude, Geology 1978.

SERVICE ON GOVERNMENT ADVISORY BOARDS (SELECTED)

National Research Council Committee on Strategic Research for Integrated Water Resources Management. Member: 2013.

US Army Corps of Engineers Technical Review Committee for the Greater Mississippi Basin Post-Flood Assessment. Member: 2012-2014

National Research Council Committee on Hydrology, Ecology, and Fishes of the Klamath River Basin

Member: 2006-2007

Federal Interagency Flood Risk Management Committee Member: 2005-2007

Environmental Advisory Board to the Chief of the US Army Corps of Engineers: Member: 2002-2007

CALFED Bay-Delta Program Ecosystem Restoration Program Science Board: Member: 1999-2005

LANGUAGES

English (native speaker), French (excellent), Spanish (basic)

COUNTRY EXPERIENCE

Cambodia, China, Ecuador, Egypt, France, Laos, Nicaragua, Nigeria, Portugal, Spain, Switzerland, UK, US, Vietnam

CURRENT/RECENT PROJECT EXPERIENCE

Subsurface flow processes in gravel rivers and the quality of Chinook salmon (*Oncorhynchus tshawytscha*) spawning habitat under managed flow regimes. Principal investigator on field study of bed substrate, morphology, and subsurface flow processes downstream of dams in the San Joaquin River. (supervising Erin Bray, post-doctoal scholar) Funded by the California Delta Science/Sea Grant Program. 2014-2015.

Compilation and Assessment of River Restoration Evaluation Metrics. Principal investigator for review of metrics used in US Bureau of Reclamation restoration projects in western North America. Evaluations of restoration programs have relied heavily on easily quantified metrics such as acres restored or length of streambank restored, but now seek to develop more ecologically meaningful metrics to assess interactions between physical habitat and ultimate biological goals. (supervising Zan Rubin, PhD student) Funded by US Bureau Reclamation Science and Technology Program. 2014-2015.

Consultation on geomorphic aspects of restoration of the River Aire. Collaborative with ADM Architects, Geneva. Funded by the Canton of Geneva, 2010-present.

Post-project Appraisals of Riparian Restoration Projects, Lower Colorado River. Principal investigator for critical review of restoration plans, monitoring data, and collection of field data to assess success of the US Bureau of Reclamation's restoration efforts along the lower Colorado River (Arizona-California) under the Multi-Species Conservation Plan. Conducted geomorphic analysis and independent sampling/analysis of insect populations as missing metric in evaluation of project success. (supervising PhD student Zan Rubin and post-doctoral scholar Blanca Rios) Funded by the Walton Family Fund. 2011-2013.

Assessment of habitat complexity and ecological functions induced from gravel bar formation by gravel augmentation and channel rehabilitation activities. Principal investigator on field study of shallow groundwater exchange, nutrient cycling, coarse particulate organic matter dynamics, and temperature patterns studied through extensive field work on the Trinity River downstream of Lewiston Dam. Funded by the US Bureau of Reclamation Science and Technology Program. (supervising post-doctoral scholar Giyoung Ock) 2012-2013

Adaptation to Variability: Water Management in Mediterranean Climates

Principal investigator for an interdisciplinary faculty seminar exploring the strong parallels among Mediterranean-climate regions and the potential to share design precedents and solutions to these challenges, including recent innovations in water management in the European Union. (supervising PhD students Zan Rubin and Jennifer Natali) Funded by Institute for International Studies. 2011-2015.

Habitat restoration in the context of watershed prioritization: the ecological performance of urban streams restoration projects in Portland, Oregon. Principal investigator on project to collect new field data and use archived prior data on aquatic conditions of restoration projects and reference sites within Portland, to assess ecological performance of restoration projects. Research collaborative with the City of Portland, Oregon, and with post-doctoral scholar Blanca Rios. Post-doctoral scholar Rios funded by Prometeo program of the Secretaría Nacional de Educación Superior, Ciencia, Tecnología e Innovación of Ecuador. (supervising post-doctoral scholar Blanca Rios) 2012-2013.

Sustainable Reservoir Sediment Management. Lead scientist for Natural Heritage Institute in review of collective experience from five continents in managing reservoir sediments and mitigating downstream sediment starvation, resulting in recommendations for utilizing sediment management approaches to sustain reservoir capacity and minimize environmental impacts of dams. Summary published in peer-reviewed journal *Earth's Future*, see http://onlinelibrary.wiley.com/doi/10.1002/2013EF000184/pdf Funded by the USAID project "A Climate Resilient Mekong: Maintaining the Flows that Nourish Life". 2012-2015.

Cumulative Sediment Starvation from Planned Dams on the Mekong River

Lead scientist for Natural Heritage Institute on analysis of cumulative sediment trapping by dams under construction or proposed for the Lower Mekong River. This project delineated nine geomorphic regions with distinct sediment yields, and using the 3W model calculated cumulative sediment trapping by these dams under various dam scenarios. Hosted an expert workshop to identify impacts on the Mekong Delta and research priorities. Funded by the USAID through the project "A Climate Resilient Mekong: Maintaining the Flows that Nourish Life", and with initial funding from the Mekong River Commission. 2009-2014.

Analysis of channel change, Benue River, Yola, Nigeria. Analyzed recent channel movements, probable effects of Lagbo Dam, and conducted stability analysis for siting of intake for municipal water supply. Collaborative with Vogler Engineering. Funded by the City of Yola, Nigeria. 2009.

PEER-REVIEWED PUBLICATIONS (SELECTED RECENT)

Rubin, Z.K., G.M. Kondolf, and P. Carling. 2014. Anticipated geomorphic impacts from Mekong basin dam construction. *International Journal of River Basin Management* doi: 10.1080/15715124.2014.981193

G.M. Kondolf, Z.K. Rubin, J.T. Minear. 2014. Dams on the Mekong: Cumulative sediment starvation. *Water Resources Research* 50, doi:10.1002/2013WR014651

G. M. Kondolf, Y. Gao, G.W. Annandale, G.L. Morris, E. Jiang, R. Hotchkiss, P. Carling, B. Wu, J. Zhang, C. Peteuil, H-W. Wang, C. Yongtao, K. Fu, Q. Guo, T. Sumi, Z. Wang, Z. Wei, C. Wu, C.T. Yang. 2014. Sustainable sediment management in reservoirs and regulated rivers: experiences from five continents. *Earth's Future* doi: 10.1002/eft2 2013EF000184 online at http://onlinelibrary.wiley.com/doi/10.1002/2013EF000184/pdf

Habersack, H., D. Haspel, and G.M. Kondolf. 2014. Large rivers in the Anthropocene: insights and tools for understanding climatic, land-use, and reservoir Influences. *Water Resources Research* 50: 3641–3646, doi:10.1002/2013WR014731.

Yin, X-A., Z-F. Yang, G.E. Petts, and G.M Kondolf. 2014. A reservoir operating method for riverine ecosystem protection, reservoir sedimentation control and water supply. *Journal of Hydrology,* 512:379–387. http://dx.doi.org/10.1016/j.jhydrol.2014.02.037

Rios-Touma, B., C. Prescott, S. Axtell, and G.M. Kondolf. 2014. Habitat restoration in the context of watershed prioritization: the ecological performance of urban streams restoration projects in Portland, OR. *River Research and Applications* DOI: 10.1002/rra.2769

Wang, H-W, and G.M. Kondolf. 2013. Upstream sediment-control dams: five decades of experience in the rapidly-eroding Dahan River Basin, Taiwan, *Journal of the American Water Resources Association,* DOI: 10.1111/jawr.12141

Kondolf, G.M., K. Podolak, and T.E. Grantham. 2013. Restoring Mediterranean-climate rivers. *Hydrobiologia* 719:527-545. DOI 10.1007/s10750-012-1363-y

Deitch, M.J., and G. M. Kondolf. 2012. Consequences of variations in magnitude and duration of an instream environmental flow threshold across a longitudinal gradient. *Journal of Hydrology* 420–421: 17–24. DOI:10.1016/j.jhydrol.2011.11.003

Lassettre, N.S. and G.M. Kondolf. 2011. Large wood in urban stream channels: re-defining the problem. *River Research and Applications*. DOI: 10.1002/rra.1538

Minear, J.T. and G.M. Kondolf. 2009. Estimating reservoir sedimentation rates at large spatial- and temporal-scales: a case study of California. *Water Resources Research* 45, W12502, doi:10.1029/2007WR006703

Kondolf, G.M., S. Anderson, R. Lave, L. Pagano, A. Merelender, and E. Bernhardt. 2007. Two decades of river restoration in California: What can we learn? *Restoration Ecology* 15(3):516-523.

Kondolf, G.M., and R.J. Batalla. 2005. Hydrological effects of dams and water diversions on rivers of Mediterranean-climate regions: Examples from California. In C. Garcia and R.J. Batalla (eds.) *Catchment dynamics and river processes: Mediterranean and other climate regions*. Elsevier, London. pp.197-211.

Batalla, R.J., C.M. Gomez, and G.M. Kondolf. 2004. Reservoir-induced hydrologic changes in the Ebro River basin (NE Spain) . *Journal of Hydrology* 290, 117-136.

Kondolf, G.M., H. Piégay, and N. Landon. 2002. Channel response to increased and decreased bedload supply from land-use change: Contrasts between two catchments. *Geomorphology* 45:35-51.

Kondolf, G.M. 2001. Planning approaches to mitigating adverse human impacts on land-inland-water ecotones. *Ecohydrology and Hydrobiology* 1:111-116.

Kondolf, G.M., E.W. Larsen, and J.G. Williams. 2000. Measuring and modeling the hydraulic environment for assessing instream flows. *North American Journal of Fisheries Management* 20:1016-1028.

Kondolf, G.M. 1998. Environmental effects of aggregate extraction from river channels and floodplains. In P. Bobrowsky (ed.) *Aggregate Resources: A Global Perspective* (pp. 113-129). Balkema, Rotterdam.

Kondolf, G.M. 1997. Hungry water: Effects of dams and gravel mining on river channels. *Environmental Management* 21(4):533-551.

Kondolf, G.M., and P.R. Wilcock. 1996. The flushing flow problem: Defining and evaluating objectives. *Water Resources Research* 32(8):2589-2599.

Kondolf, G.M. 1995. Managing bedload sediments in regulated rivers: Examples from California, USA. *Geophysical Monograph* 89:165-176.

Kondolf, G.M. 1994. Environmental planning in the regulation and management of instream gravel mining in California. *Landscape and Urban Planning* 29:185-199.

Kondolf, G.M. 1994. Geomorphic and environmental effects of instream gravel mining. *Landscape and Urban Planning* 28:225-243.

Kondolf, G.M. 1993. The reclamation concept in regulation of gravel mining in California. *Journal of Environmental Planning and Management* 36:397-409.

Kondolf, G.M., and M.L. Swanson. 1993. Channel adjustments to reservoir construction and instream gravel mining, Stony Creek, California. *Environmental Geology and Water Science* 21:256-269.

Kondolf, G.M., and M.G. Wolman. 1993. The sizes of salmonid spawning gravels. *Water Resources Research* 29:2275-2285.

BOOKS

Kondolf, G.M., and H. Piégay, eds. 2003. *Tools in fluvial geomorphology*. John Wiley & Sons, Chichester, 696 pp. ***Second Edition forthcoming in 2015***

TECHNICAL REPORTS (SELECTED RECENT)

National Research Council. 2013. *Delta Waters: Research to Support Integrated Water and Environmental Management in the Lower Mississippi River*. The National Academies Press, Washington, DC.

Mekong River Commission. 2009. *Design guidelines for Mekong Mainstem Dams*. (co-author of sediment-related guidelines) March 2009.

Kondolf, G.M., M. Smeltzer, and L. Kimball. 2001. Freshwater gravel mining and dredging issues. White paper prepared for the Washington Departments of Fish and Wildlife, Ecology, and Transportation, Olympia. Report No. CEDR-R01-02, University of California, Berkeley. Available at: http://www.wdfw.wa.gov/hab/ahg/freshdrg.pdf.

EXPERT TESTIMONY (SELECTED RECENT)

2013. Provided written expert regarding environmental flow requirements of the Kishenganga River, India-Pakistan in a case before the Court of Arbitration on the Indus Waters, Kishenganga Arbitration, the Hague, Netherlands.

2012-2015. Provided written expert testimony regarding environmental impacts of road construction along the Rio San Juan and historical changes in channels in the delta of the Rio San Juan, Nicaragua and Costa Rica, in a case before the International Court of Justice, the Hague, Netherlands.

2010. Testified regarding water diversions and measurements of streamflow in Napa and Sonoma counties before the California State Water Resources Control Board.

RECENT AWARDS AND FELLOWSHIPS

Fellow of the Landscape Architecture Foundation, 2013.

Clarke Scholar at the Institute for Water Resources, US Army Corps Engineers, Washington DC 2011.

Award of Distinction. Council of Educators in Landscape Architecture, 2007.

Senior Scholar Research and Teaching Award Fulbright Commission. Portugal 2001, France 1997-98.